

TITLE OF THE INVENTION

DELAY EQUALIZER, OPTICAL TRANSMITTER USING SAME
DELAY EQUALIZER, AND OPTICAL TRANSMISSION SYSTEM

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BACKGROUND OF THE INVENTION

1) Field of the Invention

The present invention relates to a delay equalizer for equalizing a delay characteristic of a transmission line, an optical transmitter for performing frequency modulation (FM) of frequency-multiplexed (frequency-division-multiplexed) multi-channel signals in optical transmission in batches, which exert influence on the signal transmission quality after transmission depending upon a delay characteristic of a transmission line, and an optical transmission system using this optical transmitter.

15 2) Description of the Related Art

So far, as a delay equalizer, there has been known an equalizer disclosed in Japanese Unexamined Patent Publication No. 03 (HEI)-3411. Fig. 18 is an illustration of a circuit arrangement of a conventional delay equalizer. The circuit arrangement of this delay equalizer is such that a series circuit comprising an inductor L5 and a resistor R8 and a series circuit comprising capacitors C5 and C6 are connected in parallel with each other between input and output terminals and a connection between the capacitors C5 and C6 is grounded through a series circuit comprising an inductor L6, a capacitor C7 and a resistor R9. In this arrangement, the curvature

component of amplitude/frequency characteristics steps up as the resistance of the resistors R8 and R9 increase, which causes an enhancement in delay compensation.

In addition, a conventional optical transmitter made to
5 frequency-modulate frequency-multiplexed multi-channel signals simultaneously and an optical transmission system using this optical transmitter have been known by Japanese Unexamined Patent Publication No. 8 (HEI)-274714. Fig. 19 is a block diagram showing a configuration of the conventional optical transmission system, where an
10 optical transmitter 4 is shown as comprising a frequency modulator 1 and an optical modulator 3 and an optical receiver 8 is shown as comprising an optical receive unit 6 and a frequency demodulator 7. In this configuration, frequency-multiplexed multi-channel signals are simultaneously frequency-modulated in the frequency modulator 1 and
15 optically intensity-modulated in the optical modulator 3, before transmitted through an optical fiber transmission line 5. On the other hand, in the optical receiver 8, the collectively frequency-modulated signal is photoelectrically converted (optical-electrical-converted) in the optical receive unit 6 and frequency-demodulated in the frequency
20 demodulator 7, thereby regenerating frequency-multiplexed multi-channel signals.

In the case of the conventional delay equalizer, however, difficulty is encountered in flexibly varying a delay equalization quantity according to transmission line undergoing delay equalization, which
25 creates a problem in coping flexibly with variations of delay

characteristics after system installation, and although equalization is achievable with respect to delay in the vicinity of the resonance frequency depending on the conductance of a conductor and the capacitance of a capacitor, difficulty is experienced in accomplishing delay equalization throughout a wide band of frequencies so that it is inapplicable to a system requiring the delay equalization over a wide band of frequencies.

SUMMARY OF THE INVENTION

10 The present invention has been developed with a view to eliminating the above-mentioned problems, and it is therefore an object of the invention to provide a delay equalizer capable of coping flexibly with variations of delay characteristics of transmission lines, of equalizing the delay characteristics over a wideband of frequencies and
15 of offering delay equalization characteristics to delay characteristics of transmission lines, and an optical transmitter and optical transmission system using this delay equalizer.

For this purpose, in accordance with an aspect of the present invention, there is provided a delay equalizer connected between input
20 and output terminals and comprising an inductor and a capacitor, which constitute a resonance circuit with a given resonance frequency determining a center frequency for delay equalization, and a variable resistor made variable in resistance, with the Q value of the resonance circuit being varied by a change of the resistance of the variable
25 resistor to vary a quantity of the delay equalization. With this circuit

arrangement, the resistance value of the variable resistor can be changed to vary the quantity or degree of delay equalization.

Furthermore, in accordance with another aspect of the present invention, there is provided a delay equalizer connected between input and output terminals and comprising an inductor and a variable capacitance capacitor made variable in capacitance, which constitute a resonance circuit with a given resonance frequency determining a center frequency for delay equalization, and a variable resistor made variable in resistance, with the center frequency for the delay equalization being made variable with a variation of the capacitance of the variable capacitance capacitor, and a Q value of the resonance circuit being varied with a variation of resistance of the variable resistor to vary the degree of delay equalization. With this circuit arrangement, the capacitance of the variable capacitance capacitor can be varied to change the center frequency for varying delay characteristic while the resistance of the variable resistor can be varied to change the degree of delay equalization.

In the foregoing delay equalizer, a PIN diode is used as the variable resistor and a power circuit is provided to control a current flowing through the PIN diode, with the current flowing through the PIN diode being controlled to change an internal resistance of the PIN diode so that the degree of delay equalization is made variable. That is, with this circuit arrangement, the internal resistance is varied by controlling the current flowing through the PIN diode, thereby varying the degree of delay equalization.

In addition, in the foregoing delay equalizer, a voltage variable capacitor whose capacitance is made variable through voltage control is used as the variable capacitor and a power circuit is provided to control a voltage across the voltage variable-capacitance capacitor, with the voltage across the voltage variable capacitor being controlled to vary the resonance frequency of the resonance circuit comprising the inductor and the capacitor so that the center frequency for the delay equalization is made variable. That is, with this circuit arrangement, the resonance frequency of the resonance circuit is varied by controlling the voltage value across the voltage variable capacitor, thereby changing the delay characteristic with a variation of the center frequency.

Still additionally, in the foregoing delay equalizer, an PIN diode is used as the variable resistor, a first power circuit is provided to control a current flowing through the PIN diode, a voltage variable capacitor whose capacitance is made variable under voltage control is used as the variable capacitor, and a second power circuit is provided to control a voltage across the voltage variable capacitor, with the current flowing the PIN diode being controlled by the first power circuit to vary an internal resistance of the PIN diode so that the degree of delay equalization is made variable, and the voltage across the voltage variable capacitor being controlled by the second power circuit to vary the resonance frequency of the resonance circuit so that the center frequency for the delay equalization is made variable. With this circuit arrangement, the internal resistance can be changed by controlling the

current flowing through the PIN diode, thereby varying the degree of delay equalization, and the voltage value across the voltage variable capacitor can be controlled to vary the resonance frequency of the resonance circuit comprising the inductor and the capacitor, thus
5 varying the center frequency causing a variation of the delay characteristic.

Moreover, in the foregoing delay equalizer, a plurality of delay equalizing sections each comprising an inductor, a capacitor and a variable resistor are cascade-connected between input and output
10 terminals, with resistance of the variable resistors of the delay equalizing sections being individually controlled to vary the degree of delay equalization according to center frequency of each delay equalizing section. With this circuit arrangement, the resistance of the variable resistor of each of the delay equalizing sections is controlled
15 independently to vary the degree of delay equalization, which enables the delay equalization characteristic to be freely changed over a wideband of frequencies.

Still moreover, in the foregoing delay equalizer, a plurality of delay equalizing sections each comprising an inductor, a variable
20 capacitor and a variable resistor are cascade-connected between input and output terminals, with the capacitance of the variable capacitors of the delay equalizing sections being individually controlled to vary the resonance frequency of the resonance circuit so that the center frequency for the delay equalization is made variable, and the
25 resistance of the variable resistors of the delay equalizing sections

being individually controlled to vary the degree of delay equalization according to center frequency of each delay equalizing section. With this circuit arrangement, the resonance frequency of the resonance circuit can be varied by controlling the capacitance of the variable capacitor of each of the delay equalizing sections, thus varying the center frequency causing a variation of the delay characteristic. In addition, the degree of equalization can be varied by controlling the resistance of the variable resistor of each of the delay equalizing sections, which enables the delay equalization characteristic to be freely changed over a wideband of frequencies.

In addition, in the foregoing delay equalizer, each of the delay equalizing sections includes a PIN diode serving as the variable resistor and a power circuit for controlling a current flowing through the PIN diode so that the current flowing through the PIN diode of each of the delay equalizing sections is controlled to freely vary the degree of delay equalization. With this circuit arrangement, the internal resistance of the PIN diode is changed by independently controlling the value of a current flowing through the PIN diode of each of the delay equalizing sections, which enables the degree of delay equalization to be varied over a wideband of frequencies.

Still additionally, in the foregoing delay equalizer, each of the delay equalizing sections includes a voltage variable capacitor whose capacitance is made variable in accordance through voltage control and which serves as the variable capacitor and a power circuit for controlling a voltage across the voltage variable capacitor, with the

voltage across the voltage variable capacitor of each of the delay equalizing sections is controlled to vary the resonance frequency of the resonance circuit for freely varying the center frequency at every delay equalizing section. With this circuit arrangement, the resonance frequency of the resonance circuit is varied by independently controlling a value of a voltage across the voltage variable capacitor of each of the delay equalizing sections, which varies the center frequency for varying the delay characteristic of each of the delay equalizing sections.

Still additionally, in the foregoing delay equalizer, each of the delay equalizing sections includes a PIN diode serving as the variable resistor, a first power circuit for controlling a current passing through the PIN diode, a voltage variable capacitor whose capacitance is made variable through voltage control and which services as the variable capacitor, and a second power circuit for controlling a voltage across the voltage variable capacitor, with the current flowing through the PIN diode of each of the delay equalizing sections being controlled by the first power circuit to vary the internal resistance of the PIN diode so that the degree of delay equalization is made variable at every delay equalizing section, and the voltage across the voltage variable capacitor being controlled by the second power circuit to vary the resonance frequency of the resonance circuit comprising the inductor and the capacitor so that the center frequency is made variable at every delay equalizing section. With this circuit arrangement, the resonance frequency of the resonance circuit is varied by

independently controlling the value of the voltage across the voltage variable capacitor of each of the delay equalizing sections, which independently varies the center frequency to cause a variation of the delay characteristic of each of the delay equalizing sections.

5 Furthermore, in accordance with a further aspect of the present invention, there is provided an optical transmitter comprising frequency modulating means for frequency-modulating frequency-multiplexed multi-channel signals, optical modulating means for
10 intensity-modulating signal light with batched modulated signals obtained by the frequency modulating means for optical transmission, and a delay equalizer provided before the optical modulating means and including an inductor and a capacitor, which constitute a resonance circuit with a given resonance frequency determining a center frequency for delay equalization, and a variable resistor made
15 variable in resistance, with the Q value of the resonance circuit being varied by varying the resistance of the variable resistor so that the degree of delay equalization is made variable. With this circuit arrangement, the resistance of the variable resistor of the delay equalizer is varied to equalize the delay deviation on a batched
20 frequency-modulated signal transmission line in the optical transmitter, thereby reducing the delay distortion occurring due to the delay deviation.

Still furthermore, in accordance with a further aspect of the present invention, there is provided an optical transmitter comprising
25 frequency modulating means for frequency-modulating

frequency-multiplexed multi-channel signals, optical modulating means for intensity-modulating signal light with batched modulated signals obtained by the frequency modulating means for optical transmission, and a delay equalizer provided before the optical modulating means

5 and including an inductor and a variable capacitor made variable in capacitance, which constitute a resonance circuit with a given resonance frequency which determines a center frequency for delay equalization, and a variable resistor made variable in resistance, with the center frequency for the delay equalization being made variable by

10 varying the capacitance of the variable capacitor and the Q value of the resonance circuit being made variable by varying the resistance of the variable resistor so that the degree of delay equalization is made variable. With this circuit arrangement, the value of capacitance of the variable capacitor of the delay equalizer is varied to equalize the delay

15 deviation on a batched frequency-modulated signal transmission line in the optical transmitter, thereby reducing the delay distortion occurring due to the delay deviation.

Still furthermore, in accordance with a further aspect of the present invention, there is provided an optical transmitter comprising

20 frequency modulating means for frequency-modulating frequency-multiplexed multi-channel signals, optical modulating means for intensity-modulating signal light with batched modulated signals obtained by the frequency modulating means for optical transmission, and a delay equalizer provided before the optical modulating means

25 and including an inductor and a capacitor, which constitute a

resonance circuit with a given resonance frequency determining a center frequency for delay equalization, and a PIN diode made variable in resistance, and a power circuit for controlling a current flowing through the PIN diode, with the current flowing through the PIN diode being controlled to vary an internal resistance of the PIN diode so that the degree of delay equalization is made variable. With this circuit arrangement, the current value in the PIN diode of the delay equalizer is controlled to equalize the delay deviation on a batched frequency-modulated signal transmission line in the optical transmitter, thereby reducing the delay distortion occurring due to the delay deviation.

Moreover, in accordance with a further aspect of the present invention, there is provided an optical transmitter comprising frequency modulating means for frequency-modulating frequency-multiplexed multi-channel signals, optical modulating means for intensity-modulating signal light with batched modulated signals obtained by the frequency modulating means for optical transmission, and a delay equalizer provided before the optical modulating means and including an inductor and a voltage variable capacitor made variable in capacitance through voltage control, which constitute a resonance circuit with a given resonance frequency determining a center frequency for delay equalization, a variable resistor made variable in resistance, and a power circuit for controlling a voltage across the voltage variable capacitor, with the Q value of the resonance circuit being made variable by varying the resistance of the

variable resistor so that the degree of delay equalization is made variable, and the value of the voltage across the voltage variable capacitor being controlled to vary the resonance frequency of the resonance circuit so that the center frequency for the delay

5 equalization is made variable. With this circuit arrangement, the value of capacitance of the voltage variable capacitor of the delay equalizer is varied to equalize the delay deviation on a batched frequency-modulated signal transmission line in the optical transmitter, thereby reducing the delay distortion occurring due to the delay
10 deviation.

Still moreover, in accordance with a further aspect of the present invention, there is provided an optical transmitter comprising frequency modulating means for frequency-modulating frequency-multiplexed multi-channel signals, optical modulating means for
15 intensity-modulating signal light with batched modulated signals obtained by the frequency modulating means for optical transmission, and a delay equalizer provided before the optical modulating means and including an inductor, a voltage variable capacitor made variable in capacitance through voltage control, which constitute a resonance
20 circuit with a given resonance frequency determining a center frequency for delay equalization, a PIN diode made variable in resistance, a first power circuit for controlling a current flowing through the PIN diode, and a second power circuit for controlling a voltage across the voltage variable capacitor, with the current flowing through
25 the PIN diode being controlled by the first power circuit to vary an

internal resistance of the PIN diode so that the degree of delay equalization is made variable, and the voltage across the voltage variable capacitor being controlled by the second power circuit to vary the resonance frequency of the resonance circuit so that a central

5 frequency for delay equalization is made variable. With this circuit arrangement, the resistance value of the PIN diode and the capacitance value of the voltage variable capacitor in the delay equalizer are controlled to equalize the delay deviation on a batched frequency-modulated signal transmission line in the optical transmitter,

10 thereby reducing the delay distortion occurring due to the delay deviation.

In addition, in accordance with a further aspect of the present invention, there is provided an optical transmitter comprising frequency modulating means for frequency-modulating frequency-multiplexed

15 multi-channel signals, optical modulating means for intensity-modulating signal light with batched modulated signals obtained by the frequency modulating means for optical transmission, and a delay equalizer provided before the optical modulating means and including a plurality of delay equalizing sections, each comprising

20 an inductor, a capacitor and a variable resistor, cascade-connected between input and output terminals, with the degree of delay equalization being made variable according to center frequency of each delay equalizing section by individually controlling the resistance of the variable resistor of each of the delay equalizing sections. With this

25 circuit arrangement, the delay equalizing sections cascade-connected

equalize the delay deviation on a batched frequency-modulated signal transmission line in the optical transmitter over a high band, thereby reducing the delay distortion occurring due to the delay deviation.

Still additionally, in accordance with a further aspect of the

5 present invention, there is provided an optical transmitter comprising frequency modulating means for frequency-modulating frequency-multiplexed multi-channel signals, optical modulating means for intensity-modulating signal light with batched modulated signals obtained by the frequency modulating means for optical transmission,

10 and a delay equalizer provided before the optical modulating means and including a plurality of delay equalizing sections, each comprising an inductor, a variable capacitor and a variable resistor, cascade-connected between input and output terminals, with a resonance frequency of a resonance circuit being varied by individually

15 controlling a capacitance of the variable capacitor of each of the delay equalizing sections so that a center frequency for delay equalization being made variable, and the degree of delay equalization being made variable according to center frequency by individually controlling the resistance of the variable resistor of each of the delay equalizing

20 sections. With this circuit arrangement, the delay equalizing sections cascade-connected equalize the delay deviation on a batched frequency-modulated signal transmission line in the optical transmitter over a wideband, thereby reducing the delay distortion occurring due to the delay deviation.

In the optical transmitter, each of the delay equalizing sections includes a PIN diode serving as the variable resistor and a power circuit for controlling a current flowing through the PIN diode, with the current flowing through the PIN diode of each of the delay equalizing sections being controlled to vary an internal resistance of the PIN diode so that the degree of delay equalization is made variable. With this circuit arrangement, the delay equalizing sections cascade-connected equalize the delay deviation on a batched frequency-modulated signal transmission line in the optical transmitter over a wideband, thereby reducing the delay distortion occurring due to the delay deviation.

In addition, in the optical transmitter, each of the delay equalizing sections includes a voltage variable capacitor made variable in capacitance through voltage control and serving as the variable capacitor and a power circuit for controlling a voltage across the voltage variable capacitor, with the voltage value across the voltage variable capacitor of each of the delay equalizing sections being controlled to vary a resonance frequency of a resonance circuit so that a center frequency is made variable at every delay equalizing section. With this circuit arrangement, the delay equalizing sections cascade-connected equalize the delay deviation on a batched frequency-modulated signal transmission line in the optical transmitter over a wideband, thereby reducing the delay distortion occurring due to the delay deviation.

Still additionally, in the optical transmitter, each of the delay equalizing sections includes a PIN diode serving as the variable

resistor, a first power circuit for controlling a current flowing through the PIN diode, a voltage variable capacitor made variable in capacitance through voltage control and serving as the variable capacitor, and a second power circuit for controlling a voltage across the voltage

5 variable capacitor, with the current flowing through the PIN diode of each of the delay equalizing sections being controlled by the first power circuit to vary an internal resistance of the PIN diode so that the degree of delay equalization is made variable at every delay equalizing section, and the voltage across the voltage variable capacitor being controlled

10 by the second power circuit to vary a resonance frequency of a resonance circuit so that a center frequency is made variable at every delay equalizing section. With this circuit arrangement, the delay equalizing sections cascade-connected equalize the delay deviation on a batched frequency-modulated signal transmission line in the optical

15 transmitter over a wideband, thereby reducing the delay distortion occurring due to the delay deviation.

Furthermore, in accordance with a further aspect of the present invention, there is provided an optical transmission system comprising an optical transmitter including frequency modulating means for

20 frequency-modulating frequency-multiplexed multi-channel signals and optical modulating means for intensity-modulating signal light with batched modulated signals obtained by the frequency modulating means for optical transmission and an optical receiver for frequency-demodulating the batched frequency-modulated signal,

25 obtained by optical/electrical-converting an optical signal transmitted

from the optical transmitter, to transmit frequency-multiplexed multi-channel signals, and in the optical transmitter, a delay equalizer is provided before the optical modulating means and is composed of an inductor and a capacitor, which constitute a resonance circuit with a given resonance frequency determining a center frequency for delay equalization, and a variable resistor made variable in resistance, with a Q value of the resonance circuit being varied in accordance with a variation of the resistance of the variable resistor so that the degree of delay equalization is made variable. With this circuit arrangement, in addition to equalizing the delay deviation on the batched frequency-modulated signal transmission line, the delay equalizer can equalize the delay deviation on the batched frequency-modulated signal transmission line in the optical receiver; therefore, it is possible to reduce the delay distortion stemming from the delay deviation of the entire system from the optical transmitter to the optical receiver.

Moreover, in accordance with a further aspect of the present invention, there is provided an optical transmission system comprising an optical transmitter including frequency modulating means for frequency-modulating frequency-multiplexed multi-channel signals and optical modulating means for intensity-modulating signal light with batched modulated signals obtained by the frequency modulating means for optical transmission and an optical receiver for frequency-demodulating the batched frequency-modulated signal, obtained by optical/electrical-converting an optical signal transmitted from the optical transmitter, to transmit frequency-multiplexed

multi-channel signals, and in the optical transmitter, a delay equalizer is provided before the optical modulating means and is composed of an inductor and a variable capacitor made variable in capacitance, which constitute a resonance circuit with a given resonance frequency

5 determining a center frequency for delay equalization, and a variable resistor made variable in resistance, with the center frequency for the delay equalization is made variable in accordance with a variation of the capacitance of the variable capacitor, and a Q value of the resonance circuit being varied in accordance with a variation of the
10 resistance of the variable resistor so that the degree of delay equalization is made variable. With this circuit arrangement, in addition to equalizing the delay deviation on the batched frequency-modulated signal transmission line, the delay equalizer can equalize the delay deviation on the batched frequency-modulated
15 signal transmission line in the optical receiver; therefore, it is possible to reduce the delay distortion stemming from the delay deviation of the entire system from the optical transmitter to the optical receiver.

Still moreover, in accordance with a further aspect of the present invention, there is provided an optical transmission system comprising
20 an optical transmitter including frequency modulating means for frequency-modulating frequency-multiplexed multi-channel signals and optical modulating means for intensity-modulating signal light with batched modulated signals obtained by the frequency modulating means for optical transmission and an optical receiver for
25 frequency-demodulating the batched frequency-modulated signal,

obtained by optical/electrical-converting an optical signal transmitted from the optical transmitter, to transmit frequency-multiplexed multi-channel signals, and in the optical transmitter, a delay equalizer is provided before the optical modulating means and is composed of an inductor and a capacitor, which constitute a resonance circuit with a given resonance frequency determining a center frequency for delay equalization, a PIN diode made variable in resistance, and a power circuit for controlling a current passing through the PIN diode, with a current flowing through the PIN diode being controlled to vary an internal resistance of the PIN diode so that the degree of delay equalization is made variable. With this circuit arrangement, in addition to equalizing the delay deviation on the batched frequency-modulated signal transmission line, the delay equalizer can equalize the delay deviation on the batched frequency-modulated signal transmission line in the optical receiver; therefore, it is possible to reduce the delay distortion stemming from the delay deviation of the entire system from the optical transmitter to the optical receiver.

Furthermore, in accordance with a further aspect of the present invention, there is provided an optical transmission system comprising an optical transmitter including frequency modulating means for frequency-modulating frequency-multiplexed multi-channel signals and optical modulating means for intensity-modulating signal light with batched modulated signals obtained by the frequency modulating means for optical transmission and an optical receiver for frequency-demodulating the batched frequency-modulated signal,

obtained by optical/electrical-converting an optical signal transmitted from the optical transmitter, to transmit frequency-multiplexed multi-channel signals, and in the optical transmitter, a delay equalizer is provided before the optical modulating means and is composed of an inductor and a voltage variable capacitor made variable in capacitance through voltage control, which constitute a resonance circuit with a given resonance frequency determining a center frequency for delay equalization, a variable resistor made variable in resistance, and a power circuit for controlling a voltage across the voltage variable capacitor, with a Q value of the resonance circuit being varied in accordance with a variation of the resistance of the variable resistor so that the degree of delay equalization is made variable, and the voltage across the voltage variable capacitor being controlled to vary a resonance frequency of the resonance circuit so that the center frequency for the delay equalization is made variable. With this circuit arrangement, in addition to equalizing the delay deviation on the batched frequency-modulated signal transmission line, the delay equalizer can equalize the delay deviation on the batched frequency-modulated signal transmission line in the optical receiver; therefore, it is possible to reduce the delay distortion stemming from the delay deviation of the entire system from the optical transmitter to the optical receiver.

Still furthermore, in accordance with a further aspect of the present invention, there is provided an optical transmission system comprising an optical transmitter including frequency modulating

means for frequency-modulating frequency-multiplexed multi-channel signals and optical modulating means for intensity-modulating signal light with batched modulated signals obtained by the frequency modulating means for optical transmission and an optical receiver for frequency-demodulating the batched frequency-modulated signal, obtained by optical/electrical-converting an optical signal transmitted from the optical transmitter, to transmit frequency-multiplexed multi-channel signals, and in the optical transmitter, a delay equalizer is provided before the optical modulating means and is composed of an inductor and a voltage variable capacitor made variable in capacitance through voltage control, which constitute a resonance circuit with a given resonance frequency determining a center frequency for delay equalization, and a PIN diode made variable in resistance, a first power circuit for controlling a current flowing through the PIN diode and a second power circuit for controlling a voltage across the voltage variable capacitor, with the current flowing through the PIN diode being controlled by the first power circuit to vary an internal resistance of the PIN diode so that the degree of delay equalization is made variable, while in the delay equalizer, the voltage across the voltage variable capacitor being controlled by the second power circuit to vary a resonance frequency of the resonance circuit so that the center frequency for the delay equalization is made variable. With this circuit arrangement, in addition to equalizing the delay deviation on the batched frequency-modulated signal transmission line, the delay equalizer can equalize the delay deviation on the batched

frequency-modulated signal transmission line in the optical receiver; therefore, it is possible to reduce the delay distortion stemming from the delay deviation of the entire system from the optical transmitter to the optical receiver.

- 5 In addition, in accordance with a further aspect of the present invention, there is provided an optical transmission system comprising an optical transmitter including frequency modulating means for frequency-modulating frequency-multiplexed multi-channel signals and optical modulating means for intensity-modulating signal light with
10 batched modulated signals obtained by the frequency modulating means for optical transmission and an optical receiver for frequency-demodulating the batched frequency-modulated signal, obtained by optical/electrical-converting an optical signal transmitted from the optical transmitter, to transmit frequency-multiplexed
15 multi-channel signals, and in the optical transmitter, a delay equalizer is provided before the optical modulating means and is composed of a plurality of delay equalizing sections, each including an inductor, a capacitor and a variable resistor, cascade-connected between input and output terminals, with a resistance of the variable resistor of each
20 of the delay equalizing sections being controlled individually so that the degree of delay equalization is made variable according to center frequency of each of the delay equalizing sections. With this circuit arrangement, in addition to equalizing the delay deviation on the batched frequency-modulated signal transmission line, the plurality of
25 delay equalizing sections of the delay equalizer in the optical

transmitter can equalize the delay deviation on the batched frequency-modulated signal transmission line in the optical receiver over a wideband; therefore, it is possible to reduce the delay distortion stemming from the delay deviation of the entire system from the optical transmitter to the optical receiver.

Still additionally, in accordance with a further aspect of the present invention, there is provided an optical transmission system comprising an optical transmitter including frequency modulating means for frequency-modulating frequency-multiplexed multi-channel signals and optical modulating means for intensity-modulating signal light with batched modulated signals obtained by the frequency modulating means for optical transmission and an optical receiver for frequency-demodulating the batched frequency-modulated signal, obtained by optical/electrical-converting an optical signal transmitted from the optical transmitter, to transmit frequency-multiplexed multi-channel signals, and in the optical transmitter, a delay equalizer is provided before the optical modulating means and is composed of a plurality of delay equalizing sections, each including an inductor, a variable capacitor and a variable resistor, cascade-connected between input and output terminals, with a capacitance of the variable capacitor of each of the delay equalizing sections being control individually to vary a resonance frequency of a resonance circuit so that a center frequency for delay equalization is made variable, and a resistance of the variable resistor of each of the delay equalizing sections being controlled individually so that the degree of delay equalization is made

variable according to center frequency of each of the delay equalizing sections. With this circuit arrangement, in addition to equalizing the delay deviation on the batched frequency-modulated signal transmission line, the plurality of delay equalizing sections of the delay equalizer in the optical transmitter can equalize the delay deviation on the batched frequency-modulated signal transmission line in the optical receiver over a wideband; therefore, it is possible to reduce the delay distortion stemming from the delay deviation of the entire system from the optical transmitter to the optical receiver.

In the foregoing optical transmission system, each of the delay equalizing sections includes a PIN diode serving as the variable resistor and a power circuit for controlling a current value flowing through the PIN diode, with the current flowing through the PIN diode of each of the delay equalizing sections being controlled to vary the internal resistance of the PIN diode so that the degree of delay equalization is made variable. With this circuit arrangement, in addition to equalizing the delay deviation on the batched frequency-modulated signal transmission line, the plurality of delay equalizing sections of the delay equalizer in the optical transmitter can equalize the delay deviation on the batched frequency-modulated signal transmission line in the optical receiver over a wideband; therefore, it is possible to reduce the delay distortion stemming from the delay deviation of the entire system from the optical transmitter to the optical receiver.

In addition, in the foregoing optical transmission system, each of the delay equalizing sections includes a voltage variable capacitor made variable in capacitance through voltage control and serving as the variable capacitor and a power circuit for controlling a voltage across the voltage variable capacitor, with the voltage value across the voltage variable capacitor of each of the delay equalizing sections being controlled to vary a resonance frequency of a resonance circuit so that a center frequency is made variable according to delay equalizing section. With this circuit arrangement, in addition to equalizing the delay deviation on the batched frequency-modulated signal transmission line, the plurality of delay equalizing sections of the delay equalizer in the optical transmitter can equalize the delay deviation on the batched frequency-modulated signal transmission line in the optical receiver over a wide band; therefore, it is possible to reduce the delay distortion stemming from the delay deviation of the entire system from the optical transmitter to the optical receiver.

Still additionally, in the foregoing optical transmission system, each of the delay equalizing sections includes a PIN diode serving as the variable resistor, a first power circuit for controlling a current flowing through the PIN diode, a voltage variable capacitor made variable in capacitance through voltage control and serving as the variable capacitor, and a second power circuit for controlling a voltage across the voltage variable capacitor, with the current flowing the PIN diode of each of the delay equalizing sections being controlled by the first power circuit to vary the internal resistance of the PIN diode so

that the degree of delay equalization is made variable according to delay equalizing section, and the voltage across the voltage variable capacitor of each of the delay equalizing sections being controlled by the second power circuit to vary a resonance frequency of a resonance circuit so that a center frequency is made variable according to delay equalizing section. With this circuit arrangement, in addition to equalizing the delay deviation on the batched frequency-modulated signal transmission line, the plurality of delay equalizing sections of the delay equalizer in the optical transmitter can equalize the delay deviation on the batched frequency-modulated signal transmission line in the optical receiver over a wideband; therefore, it is possible to reduce the delay distortion stemming from the delay deviation of the entire system from the optical transmitter to the optical receiver.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and features of the present invention will become more readily apparent from the following detailed description of the preferred embodiments taken in conjunction with the accompanying drawings in which:

Fig. 1 is a circuit diagram showing an arrangement of an delay equalizer according to a first embodiment of the present invention;

Fig. 2 is an illustration of a variation characteristic of delay equalization in a delay equalizer according to the invention;

Fig. 3 is a circuit diagram showing an arrangement of an delay equalizer according to a second embodiment of the present invention;

Fig. 4 is an illustration of a variation characteristic of a center frequency in a delay equalizer according to the invention;

Fig. 5 is a circuit diagram showing an arrangement of an delay equalizer according to a third-embodiment of the present invention;

5 Fig. 6 is a circuit diagram showing an arrangement of an delay equalizer according to a fourth embodiment of the present invention;

Fig. 7 is a circuit diagram showing an arrangement of an delay equalizer according to a fifth embodiment of the present invention;

10 Fig. 8 is a circuit diagram showing an arrangement of an delay equalizer according to a sixth embodiment of the present invention;

Fig. 9 is an illustration of a variation characteristic of a delay characteristic in the delay equalizer according to the sixth embodiment of the invention;

15 Fig. 10 is a characteristic illustration of an example of a variation state of a delay characteristic in the delay equalizer according to the sixth embodiment of the invention;

Fig. 11 is a characteristic illustration of an example of a variation state of a delay characteristic in the delay equalizer according to the sixth embodiment of the invention;

20 Fig. 12 is a circuit diagram showing an arrangement of an delay equalizer according to a seventh embodiment of the present invention;

Fig. 13 is a circuit diagram showing an arrangement of an delay equalizer according to an eighth embodiment of the present invention;

25 Fig. 14 is a circuit diagram showing an arrangement of an delay equalizer according to a ninth embodiment of the present invention;

Fig. 15 is a circuit diagram showing an arrangement of an delay equalizer according to a tenth embodiment of the present invention;

Fig. 16 is a block diagram showing a configuration of an optical transmitter according to the invention;

5 Fig. 17 is a block diagram showing a configuration of an optical transmission system using an optical transmitter according to the invention;

Fig. 18 is a circuit diagram showing an arrangement of a delay equalizer in the related art; and

10 Fig. 19 is a block diagram showing a configuration of an optical transmission system using a related art optical transmitter.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiments of the present invention will be described
15 hereinbelow with reference to the drawings. The parts substantially identical or corresponding in function to those described above in the related art will be marked with the same reference numerals.

(Delay Equalizer According to First Embodiment)

Fig. 1 is a circuit diagram showing an arrangement of a delay
20 equalizer according to a first embodiment of the present invention. This delay equalizer is made up of a series circuit comprising a variable resistor $Rr1$, inductor $L1$ and a capacitor $C1$ and a series circuit comprising a resistor $R2$ and resistors $R3$, $R4$ connected in parallel therewith, and a resistor $R5$ placed between the resistors $R3$ and $R4$
25 and grounded, between input and output terminals.

A description will be given hereinbelow of a circuit operation in this circuit arrangement. In this circuit arrangement, a resonance frequency of a resonance circuit comprising the inductor L1 and the capacitor C1 determines a center frequency in a delay characteristic which causes variation of a delay characteristic. Fig. 2 is a delay characteristic illustration of variation of quantity of delay equalization in this circuit arrangement, where the horizontal axis represents frequencies and the vertical axis represents delay quantities. When the resistance of the variable resistor Rr1 varies by being controlled from the external, a variation of the Q value of the resonance circuit occurs as shown in the illustration.

As described above, according to this embodiment, the control from the external produces a variation of the delay equalization quantity, thus flexibly coping with variations of delay characteristics in a transmission line so that a delay equalization characteristic suitable for a delay characteristic of a transmission line is attainable.

(Delay Equalizer According to Second Embodiment)

Fig. 3 is a circuit diagram showing an arrangement of a delay equalizer according to a second embodiment of the present invention. In Fig. 3, the same parts as those in the first embodiment are marked with the same reference numerals, and the detailed description thereof will be omitted for brevity. In the second embodiment, a variable capacitor (variable-capacitance capacitor) Cr1 is used in place of the capacitor C1 in the first embodiment.

In an operation of this circuit arrangement, the capacitance of the capacitor Cr1 is varied by being controlled from the external to vary the resonance frequency of a resonance circuit comprising the inductor L1 and the capacitor Cr1, thereby varying the center frequency itself to vary the delay characteristic as shown in the characteristic illustration of Fig. 4. In addition, the resistance of the variable resistor Rr1 is varied by being controlled from the external, thereby varying the Q value of the resonance circuit so that the delay equalization quantity varies as shown in the characteristic illustration of Fig. 2.

As described above, according to this embodiment, the center frequency is varied by being controlled from the external to vary the delay characteristic, and the delay equalization quantity is varied in like manner, which permits coping more flexibly with the variation of the delay characteristic of a transmission line as compared with the delay equalizing circuit according to the first embodiment.

(Delay equalizer According to Third Embodiment)

Fig. 5 is a circuit diagram showing an arrangement of a delay equalizer according to a third embodiment of the present invention. In Fig. 5, the same parts as those in the first and second embodiments are marked with the same reference numerals, and the detailed description thereof will be omitted for brevity. In the third embodiment, a PIN diode D1 is used in place of the variable resistor Rr1 in the first embodiment, and a power circuit is additionally provided to supply a current to this PIN diode D1. This power circuit is designed to supply power from a power source V1 through an inductor L2 and a resistor

R6 to the PIN diode D1. A capacitor C2 is connected in parallel with the inductor L2, and an inductor L3, whose one end is grounded, is connected at the other end to an input terminal.

In an operation of the aforesaid circuit arrangement, a center
5 frequency causing a variation of the delay characteristic is determined by the resonance frequency of the resonance circuit comprising the inductor L1 and the capacitor C1. In addition, when a supply voltage V1 is varied from the external, a value of current flowing through the PIN diode D1 varies to control an internal resistance value of the PIN
10 diode D1 so that the Q value of the resonance circuit varies to vary the delay equalization quantity as shown in the characteristic illustration of Fig. 2.

As described above, according to this embodiment, the delay
equalization quantity is varied with a simple circuit in which voltage
15 control is implemented from the external, thus coping flexibly with variation of the delay characteristic of a transmission line to provide a delay equalization characteristic suitable for the delay characteristic of the transmission line.

(Delay Equalizer According to Fourth Embodiment)

20 Fig. 6 is a circuit diagram showing an arrangement of a delay equalizer according to a fourth embodiment of the present invention. In Fig. 6, the same parts as those in the first to third embodiments are marked with the same reference numerals, and the detailed description thereof will be omitted for brevity. In the fourth embodiment, a voltage
25 variable capacitor (voltage variable-capacitance capacitor) C2 and a

capacitor C4 are used in place of the variable capacitor Cr1 in the second embodiment, and a power circuit for varying a voltage to the voltage variable capacitor D2 is provided which is shown as being composed of an inductor L4, a capacitor C3 and a resistor R7.

5 In an operation of the above-mentioned circuit arrangement, a voltage to the voltage variable capacitor D2 is varied by changing a supply voltage V2 from the external so that the resonance frequency of the resonance circuit comprising the inductor L1, the voltage variable capacitor D2 and the capacitor C4 varies, thereby varying the center
10 frequency for changing the delay characteristic as shown in Fig. 4. In addition, the resistance of the variable resistor Rr1 is controlled from the external to vary, thereby varying the Q value of the resonance circuit for changing the delay equalization quantity as shown in Fig. 2.

As described above, according to this embodiment, a simple
15 circuit arrangement is put to use, nevertheless the delay equalization quantity is varied through voltage control from the external to change the center frequency, and the control of the delay equalization quantity from the external permits coping flexibly with a variation of the delay characteristic of a transmission line and offering a delay equalization
20 characteristic suitable for the delay characteristic of the transmission line.

(Delay Equalizer According to Fifth Embodiment)

Fig. 7 is a circuit diagram showing an arrangement of a delay equalizer according to a fifth embodiment of the present invention. In
25 Fig. 7, the same parts as those in the above-described first to fourth

embodiments are marked with the same reference numerals, and the detailed description thereof will be omitted for simplicity. In the fifth embodiment, a PIN diode D1 is used in place of the variable resistor Rr1 in the second embodiment, and a power circuit for supplying a
5 current to this diode D1 is provided which is shown as comprising inductors L2, L3, a capacitor C2 and a resistor R6. In addition, a voltage variable capacitor D2 and a capacitor C4 are used in place of the variable capacitor Cr1, and a power circuit for varying the voltage to be applied to the voltage variable capacitor D2 is provided which is
10 shown as comprising an inductor L4, a capacitor C3 and a resistor R7.

In an operation of this circuit arrangement, when a supply voltage V2 is varied from the external, the voltage of the voltage variable capacitor D2 varies, thus causing a variation of the resonance frequency of the resonance circuit comprising the inductor L1, the
15 voltage variable capacitor D2 and the capacitor C4 so that the center frequency, which varies (determines) the delay characteristic, is made variable as shown in the characteristic illustration of Fig. 4. Moreover, when a supply voltage V1 is varied from the external, the value of a current flowing through the PIN diode D1 varies to control the value of
20 the internal resistance of the PIN diode D1 so that the Q value of the resonance circuit varies to vary the delay equalization quantity as shown in the characteristic illustration of Fig. 2.

As described above, according to this embodiment, the delay equalization quantity is varied through two systems of voltage control
25 from the external to change the center frequency of the delay

characteristic, and the control of the delay equalization quantity from the external permits coping flexibly with a variation of the delay characteristic of a transmission line, thus offering a delay equalization characteristic optimal for the delay characteristic of the transmission line with a simple circuit arrangement.

(Delay Equalizer according to Sixth Embodiment)

Fig. 8 is a circuit diagram showing an arrangement of a delay equalizer according to a sixth embodiment of the present invention. In Fig. 8, the same parts as those in the above-described first to fifth embodiments are marked with the same reference numerals, and the detailed description thereof will be omitted for simplicity. In the sixth embodiment, N (three in the illustration) delay equalizers each corresponding to the delay equalizer according to the first embodiment are cascade-connected to form N-stage delay equalizing sections #1, #2, ..., #N. The parts constituting each of the delay equalizing sections are marked with the corresponding subscripts 1, 2, ..., N in each stage.

In an operation of this circuit arrangement, the resonance frequencies of the resonance circuits, each comprising the inductor L1 and the capacitor C1, in the delay equalizing sections #1, #2, ..., #N are made to be different from each other. Accordingly, the delay characteristic can be changed with different frequencies f_1 , f_2 , f_3 , ..., f_N in the respective delay equalizing sections #1, #2 and #N as shown in the characteristic illustration of Fig. 9. In addition, when, in each of the delay equalizing sections #1, #2, ..., #N, the resistance value of the

variable resistor R_{r1} is varied by being independently controlled from the external to vary the Q value of the corresponding resonance circuit, the delay equalization quantity can be varied independently with the frequencies f_1 , f_2 , f_3 (f_N) as shown in Fig. 9. For example, as shown in the characteristic illustration of Fig. 10, it is possible to increase the delay quantity as the frequency becomes higher, or as shown in the characteristic illustration of Fig. 11, it is possible to decrease only the delay quantity corresponding to the frequency f_2 . Thus, this circuit arrangement can provide a variety of delay equalization characteristics over a wideband of frequencies.

As described above, according to this embodiment, in each of the delay equalizing sections, the delay equalization quantity is separately varied through the control from the external, which permits coping flexibly with variation of delay characteristic of a transmission line over a wide band, thus offering a delay equalization characteristic suitable for the delay characteristic of the transmission line.

(Delay Equalizer According to Seventh Embodiment)

Fig. 12 is a circuit diagram showing an arrangement of a delay equalizer according to a seventh embodiment of the present invention. In Fig. 12, the same parts as those in the above-described first to sixth embodiments are marked with the same reference numerals, and the detailed description thereof will be omitted for simplicity. In the seventh embodiment, a variable capacitor C_{r1} is used in place of the capacitor C_1 in each of the delay equalizing sections in the sixth embodiment.

In an operation of this circuit arrangement, in each of the delay equalizing sections #1, #2, ..., #N, when the capacitance of the variable capacitor Cr1 is varied by being controlled from the external, the resonance frequency of the resonance circuit comprising the inductor L1 and the variable capacitor Cr1 varies separately so that the delay characteristic can be varied with the corresponding one of the different frequencies f1, f2, f3 (fN) as shown in the characteristic illustration of Fig. 9. In addition, in each of the delay equalizing sections #1, #2, ..., #N, when the resistance value of the variable resistor Rr1 is varied independently by control from the external, the Q value of the resonance circuit varies, thus accomplishing the independent variation of the delay equalization quantity with the corresponding one of the frequencies f1, f2, f3 (fN) as shown in the characteristic illustration of Fig. 9. Accordingly, this can provide a variety of delay equalization characteristics over a wideband of frequencies as shown in the characteristic illustrations of Figs. 10 and 11.

As described above, according to this embodiment, the control from the external can vary the delay equalization quantity at every delay equalizing section, and further can vary the center frequency which determines the delay characteristic. Accordingly, it is possible to cope flexibly with a variation of the delay characteristic of a transmission line over a wider band as compared with the above-described sixth embodiment, thus offering a delay equalization characteristic suitable for the delay characteristic of the transmission line.

(Delay Equalizer According to Eighth Embodiment)

Fig. 13 is a circuit diagram showing an arrangement of a delay equalizer according to an eighth embodiment of the present invention. In Fig. 13, the same parts as those in the above-described first to seventh embodiments are marked with the same reference numerals, and the detailed description thereof will be omitted for simplicity. In the eighth embodiment, in each of the delay equalizing sections #1, #2, ..., #N, a PIN diode D1 is used in place of the variable resistor Rr1 in the delay equalizer 2 according to the sixth embodiment and a power circuit comprising the inductors L2, L3, the capacitor C2 and the resistor R6 is provided to supply a current to the PIN diode D1.

In an operation of this circuit arrangement, in the delay equalizing sections #1, #2, ..., #N, the resonance frequencies of the resonance circuits each comprising the inductor L1 and the capacitor C1 are set to be different from each other, in which case the delay characteristic can be changed with different frequencies f_1 , f_2 , f_3 (f_N) as shown in the characteristic illustration of Fig. 9. In addition, the supply voltage V1 of each of the delay equalizing sections #1, #2, ..., #N is varied independently from the external to vary the value of the current flowing through the PIN diode D1 for independently controlling the internal resistance value of the PIN diode D1, so the Q value of the resonance circuit varies, thereby independently varying the delay equalization as shown in the characteristic illustration of Fig. 9. Whereupon, it is possible to provide a variety of delay equalization

characteristics over a wideband of frequencies as shown in Figs. 10 and 11.

As described above, according to this embodiment, the delay equalization quantity is varied in each of the delay equalizing sections through voltage control from the external, which permits coping flexibly with a variation of the delay characteristic of a transmission line over a wide band, thus offering a delay equalization characteristic suitable for the delay characteristic of the transmission line with a simple circuit arrangement.

(Delay Equalizer according to Ninth Embodiment)

Fig. 14 is a circuit diagram showing an arrangement of a delay equalizer according to a ninth embodiment of the present invention. In Fig. 14, the same parts as those in the above-described first to eighth embodiments are marked with the same reference numerals, and the detailed description thereof will be omitted for simplicity. In the ninth embodiment, a voltage variable capacitor D2 and a capacitor C4 are used in place of the variable capacitor Cr1 in each of the delay equalizing sections #1, #2, ..., #N of the delay equalizer according to the seventh embodiment. In addition, in each of the delay equalizing sections #1, #2, ..., #N, a power circuit for varying the voltage to the voltage variable capacitor D2 is provided which is composed of the inductor L4, the capacitor C3 and the resistor R7.

In an operation of this circuit arrangement, in each of the delay equalizing sections #1, #2, ..., #N, when the supply voltage V2 is varied from the external, the voltage to the voltage variable capacitor D2

varies, thereby varying the resonance frequency of the resonance circuit comprising the inductor L1, the voltage variable capacitor D2 and the capacitor C4, in which case each of the center frequencies f_1 , f_2 , f_3 (f_N) shifts to vary the delay characteristic of each of the delay equalizing sections as shown in the characteristic illustration of Fig. 9. In addition, in each of the delay equalizing sections #1, #2, ..., #N, when the resistance value of the variable resistor Rr1 is varied independently through the control from the external, the Q value of the resonance circuit varies, thereby independently varying the delay equalization quantity as shown in the characteristic illustration of Fig. 9. Accordingly, this can provide a variety of delay equalization characteristics over a wide band of frequencies as shown in Figs. 10 and 11.

As described above, according to this embodiment, although a simple circuit arrangement is put to use, the center frequencies f_1 , f_2 , f_3 (f_N), capable of varying the delay characteristic of each of the delay equalizing sections #1, #2, ..., #N, can be varied through the voltage control from the external and the delay equalization quantity of each of the delay equalizing sections #1, #2, ..., #N can be varied independently through the control from the external, which varies the delay equalization quantity over a wide band of frequencies, permits coping flexibly with a variation of the delay characteristic of a transmission line over a wide band, and provides a delay equalization characteristic suitable for the delay characteristic of the transmission line.

(Delay Equalizer According to Tenth Embodiment)

Fig. 15 is a circuit diagram showing an arrangement of a delay equalizer according to a tenth embodiment of the present invention.

In Fig. 15, the same parts as those in the above-described first to ninth

5 embodiments are marked with the same reference numerals, and the detailed description thereof will be omitted for simplicity. In the tenth embodiment, in each of the delay equalizing sections #1, #2, ..., #N, the variable resistor Rr1 in the seventh embodiment is replaced with a PIN diode D1, and a power circuit comprising the inductors L2, L3, the capacitor C2 and the resistor R6 is provided in order to supply a
10 current to the PIN diode D1. In addition, in each of the delay equalizing sections #1, #2, ..., #N, a variable capacitor Cr1 is constructed with the voltage variable capacitor D2 and the capacitor C4, and a power circuit comprising the inductor L4, the capacitor C3 and
15 the resistor R7 is further provided to vary the voltage to the voltage variable capacitor D2.

In an operation, in each of the delay equalizing sections #1, #2, ..., #N, the supply voltage V2 is varied from the external, the voltage to the voltage variable capacitor D2 varies to vary the resonance
20 frequency of the resonance circuit comprising the inductor L1, the voltage variable capacitor D2 and the capacitor C4, so each of the center frequencies f1, f2 and f3 (fN) becomes variable to change the delay characteristic of each of the delay equalizing sections #1, #2, ..., #N as shown in Fig. 9. In addition, in each of the delay equalizing
25 sections #1, #2, ..., #N, when the supply voltage V1 is varied

independently from the external, the value of the current flowing through the PIN diode D1 varies to independently control the internal resistance of the PIN diode D1, thus varying the delay equalization quantity independently as shown in the characteristic illustration of Fig.

5 9. Accordingly, it is possible to provide a variety of delay equalization characteristics over a wide band of frequencies as shown in Figs. 10 and 11.

As described above, according to this embodiment, although a simple circuit arrangement is put to use, the center frequencies f_1 , f_2 , f_3 (f_N), capable of varying the delay characteristic of each of the delay equalizing sections #1, #2, ..., #N, can be varied through the voltage control from the external and the delay equalization quantity of each of the delay equalizing sections #1, #2, ..., #N can be varied independently through the voltage control from the external, which
10 varies the delay equalization quantity over a wide band of frequencies, permits coping flexibly with a variation of the delay characteristic of a transmission line over a wide band, and provides a delay equalization characteristic suitable for the delay characteristic of the transmission line.
15

20 (First Optical Transmitter According to the Invention)

Fig. 16 is a block diagram showing a configuration of an optical transmitter according to an eleventh embodiment of the present invention. In Fig. 16, a delay equalizer 2 of an optical transmitter 4 has the same arrangement as that of the delay equalizer according to
25 the first embodiment (see Fig. 1), and the description thereof will be

omitted for brevity. This optical transmitter 4 further comprises a frequency modulator (which will be referred to hereinafter as an “FM modulator”) 1 and an optical modulator 3.

A description will be given hereinbelow of this configuration.

5 Frequency-multiplexed multi-channel signals are inputted to the optical transmitter 4 and frequency-modulated (which will be referred to hereinafter as “FM-modulated”) in the FM modulator 1 in batches. The batched FM-modulated signal obtained by the FM modulator 1 is inputted to the delay equalizer 2 to produce and add a delay
10 equalization quantity needed for equalizing a delay deviation in a batched FM-modulated signal transmission line existing within the optical transmitter 4, and then outputted to the optical modulator 3 where signal light is intensity-modulated and optically transmitted through an optical fiber transmission line 5.

15 As described above, the delay equalizer 2 can equalize the delay deviation on the batched FM-modulated signal transmission line in the optical transmitter 4, thus reducing the delay distortion stemming from the delay deviation so that high-quality transmission of frequency-multiplexed multi-channel signals is realizable.

20 (First Optical Transmission System Using Optical Transmitter According to the Invention)

Fig. 17 is a block diagram showing a configuration of an optical transmission system according to a twelfth embodiment of the present invention. In Fig. 17, the same parts as those of the optical
25 transmitter according to the eleventh embodiment are marked with the

same reference numerals, and the detailed description thereof will be omitted for brevity. In this optical transmission system, an optical transmitter 4 is composed of an FM modulator 1, a delay equalizer 2 according to the above-described first embodiment (see Fig. 1), and an optical modulator 3, while an optical receiver 8 is composed of an optical receive unit 6 and a frequency demodulator (FM demodulator) 7.

A description will be given hereinbelow of an operation of the optical transmission system thus constructed. Frequency-multiplexed multi-channel signals inputted to the optical transmitter 4 are FM-modulated in the FM modulator 1 in batches. The batched FM-modulated signals obtained in this way are inputted to the delay equalizer 2 which produces and adds a delay equalization quantity needed for equalizing the entire delay deviation on the batched FM-modulated signal transmission line existing within the optical transmitter 4, an optical fiber transmission line 5 and the batched FM-modulated signal transmission line existing within the optical receiver 8, and then outputted to the optical modulator 3 where signal light is intensity-modulated and optically transmitted through the optical fiber transmission line 5. In the optical receiver 8, the transmitted batched FM-modulated signals are optical/electrical-converted in the optical receive unit 6 and FM-demodulated in the FM demodulator 7, thereby regenerating the frequency-multiplexed multi-channel signals.

As described above, the delay equalizer 2 can equalize the delay deviation of the whole system, that is, on the batched FM-modulated

signal transmission lines of the optical transmitter 4, the optical fiber transmission line 5 and the optical receiver 8, thus reducing the delay distortion stemming from the delay deviation to realize a high-quality transmission of the frequency-multiplexed multi-channel signals.

5 (Second Optical Transmitter According to the Invention)

A second optical transmitter according to the present invention has an arrangement similar to that of the above-described first optical transmitter according to the invention except that the delay equalizer according to the second embodiment (see Fig. 2) are used instead.

10 With this arrangement, in the optical transmitter 4, frequency-multiplexed multi-channel signals inputted are FM-modulated in batches in the FM modulator 1. Subsequently, the delay equalizer 2 gives, to the obtained batched FM-modulated signals, a delay equalization quantity needed for equalizing a delay deviation in the
15 batched FM-modulated signal transmission line in the optical transmitter 4. Following this, the batched FM-modulated signals are inputted to the optical modulator 3 where signal light is intensity-modulated and optically transmitted through the optical fiber transmission line 5. In this case, since the delay equalizer 2 is
20 constructed according to the second embodiment, the center frequency is made variable by being controlled from the external to vary the delay characteristic as shown in Fig. 4, thus providing an optimal delay equalization characteristic with respect to the delay deviation on the batched FM-modulated signal transmission line in the optical
25 transmitter 4.

As described above, the delay equalizer 2 can equalize the delay deviation on the batched FM-modulated signal transmission line in the optical transmitter 4, thus reducing the delay distortion stemming from the delay deviation so that high-quality transmission of

5 frequency-multiplexed multi-channel signals is realizable.

(Second Optical Transmission System Using Optical Transmitter According to the Invention)

10 In a second optical transmission system using an optical transmitter according to the present invention, the delay equalizer 2 according to the second embodiment (see Fig. 2) is used in place of the delay equalizer 2 in the above-described first optical transmission system (see Fig. 17).

With this configuration, frequency-multiplexed multi-channel signals inputted to the optical transmitter 4 are FM-modulated in
15 batches in the FM modulator 1. The batched FM-modulated signals obtained in this way are inputted to the delay equalizer 2 which produces and adds a delay equalization quantity needed for equalizing the entire or total delay deviation on the batched FM-modulated signal transmission line existing within the optical transmitter 4, the optical
20 fiber transmission line 5 and the batched FM-modulated signal transmission line existing within the optical receiver 8, and then outputted to the optical modulator 3 where signal light is intensity-modulated and optically transmitted through the optical fiber transmission line 5. In the optical receiver 8, the transmitted batched
25 FM-modulated signals are optical/electrical-converted in the optical

receive unit 6 and FM-demodulated in the FM demodulator 7, thereby regenerating the frequency-multiplexed multi-channel signals. In this case, since the delay equalizer is constructed according to the second embodiment, the center frequency causing a variation of the delay characteristic is controllable from the external to vary, which provides the optimal delay equalization characteristic with respect to the delay deviation on the batched FM-modulated signal transmission lines of the optical transmitter 4, the optical fiber transmission line 5 and the optical receiver 8.

10 As described above, the delay equalizer 2 can equalize the delay deviation of the whole system, that is, on the batched FM-modulated signal transmission lines of the optical transmitter 4, the optical fiber transmission line 5 and the optical receiver 8, thus reducing the delay distortion stemming from the delay deviation to realize a high-quality transmission of the frequency-multiplexed multi-channel signals.

(Third Optical Transmitter according to the Invention)

A third optical transmitter according to the present invention is constructed with the delay equalizer 2 in the optical transmitter shown in Fig. 16 being replaced with the delay equalizer 2 according to the third embodiment (see Fig. 5).

20 With this arrangement, in the optical transmitter 4, frequency-multiplexed multi-channel signals inputted are FM-modulated in batches in the FM modulator 1. Subsequently, the delay equalizer 2 gives, to the obtained batched FM-modulated signals, a delay equalization quantity needed for equalizing a delay deviation in the

batched FM-modulated signal transmission line in the optical transmitter 4. Following this, the batched FM-modulated signals are inputted to the optical modulator 3 where signal light is intensity-modulated and optically transmitted through the optical fiber transmission line 5. In this case, since the delay equalizer 2 is constructed according to the third embodiment, although a simple circuit arrangement is put to use, the delay equalization quantity is made variable by being controlled from the external, thus providing an optimal delay equalization characteristic with respect to the delay deviation of the batched FM-modulated signal transmission line in the optical transmitter 4.

As described above, the delay equalizer 2 can equalize the delay deviation of the batched FM-modulated signal transmission line in the optical transmitter 4, thus reducing the delay distortion stemming from the delay deviation so that high-quality transmission of frequency-multiplexed multi-channel signals is realizable.

(Third Optical Transmission System Using Optical Transmitter According to the Invention)

In a third optical transmission system using an optical transmitter according to the present invention, the delay equalizer 2 according to the third embodiment (see Fig. 5) is used in place of the delay equalizer 2 in the above-described first optical transmission system (see Fig. 17).

With this configuration, frequency-multiplexed multi-channel signals inputted to the optical transmitter 4 are FM-modulated in

batches in the FM modulator 1. The batched FM-modulated signals obtained in this way are inputted to the delay equalizer 2 which gives a delay equalization quantity needed for equalizing the entire delay deviation on the batched FM-modulated signal transmission line in the optical transmitter 4, the optical fiber transmission line 5 and the batched FM-modulated signal transmission line in the optical receiver 8, and then outputted to the optical modulator 3 where signal light is intensity-modulated and optically transmitted through the optical fiber transmission line 5. In the optical receiver 8, the transmitted batched FM-modulated signals are optical/electrical-converted in the optical receive unit 6 and FM-demodulated in the FM demodulator 7, thereby regenerating the frequency-multiplexed multi-channel signals. In this case, since the delay equalizer 2 according to the third embodiment is put to use, the delay equalization quantity is made variable by being controlled from the external with a simple circuit, thus providing an optimal delay equalization characteristic with respect to the delay deviation on the batched FM-modulated signal transmission lines of the optical transmitter 8, the optical fiber transmission line 5 and the optical receiver 8.

As described above, the delay equalizer 2 can equalize the delay deviation of the whole system, that is, on the batched FM-modulated signal transmission lines of the optical transmitter 4, the optical fiber transmission line 5 and the optical receiver 8, thus reducing the delay distortion stemming from the delay deviation to realize a high-quality transmission of the frequency-multiplexed multi-channel signals.

(Fourth Optical Transmitter According to the Invention)

A fourth optical transmitter according to the present invention is constructed with the delay equalizer 2 in the optical transmitter shown in Fig. 16 being replaced with the delay equalizer according to the
5 fourth embodiment (see Fig. 6).

With this arrangement, in the optical transmitter 4,
frequency-multiplexed multi-channel signals inputted are FM-modulated
in batches in the FM modulator 1. Subsequently, the delay equalizer
2 gives, to the obtained batched FM-modulated signals, a delay
10 equalization quantity needed for equalizing a delay deviation in the
batched FM-modulated signal transmission line in the optical
transmitter 4. Following this, the batched FM-modulated signals are
inputted to the optical modulator 3 where signal light is
intensity-modulated and optically transmitted through the optical fiber
15 transmission line 5. In this case, since the delay equalizer 2 is
constructed according to the fourth embodiment, although a simple
circuit arrangement is put to use, the center frequency causing a
variation of the delay characteristic is controllable through the voltage
control from the external to vary, which provides the optimal delay
20 equalization characteristic with respect to the delay deviation on the
batched FM-modulated signal transmission line in the optical
transmitter 4.

As described above, the delay equalizer 2 can equalize the delay
deviation of the batched FM-modulated signal transmission line in the
25 optical transmitter 4, thus reducing the delay distortion stemming from

the delay deviation so that high-quality transmission of frequency-multiplexed multi-channel signals is realizable.

(Fourth Optical Transmission System Using Optical Transmitter According to the Invention)

5 In a fourth optical transmission system using an optical transmitter according to the present invention, the delay equalizer 2 according to the fourth embodiment (see Fig. 6) is used in place of the delay equalizer 2 in the above-described first optical transmission system (see Fig. 17).

10 With this configuration, frequency-multiplexed multi-channel signals inputted to the optical transmitter 4 are FM-modulated in batches in the FM modulator 1. The batched FM-modulated signals obtained in this way are inputted to the delay equalizer 2 which introduces a delay equalization quantity needed for equalizing the

15 entire delay deviation on the batched FM-modulated signal transmission line in the optical transmitter 4, the optical fiber transmission line 5 and the batched FM-modulated signal transmission line in the optical receiver 8, and then outputted to the optical modulator 3 where signal light is intensity-modulated and optically

20 transmitted through the optical fiber transmission line 5. In the optical receiver 8, the transmitted batched FM-modulated signals are optical/electrical-converted in the optical receive unit 6 and FM-demodulated in the FM demodulator 7, thereby regenerating the frequency-multiplexed multi-channel signals. In this case, since the

25 delay equalizer 2 according to the fourth embodiment is put to use, the

center frequency causing variation of the delay characteristic is controllable through the voltage control from the external to vary, which provides the optimal delay equalization characteristic with respect to the delay deviation on the batched FM-modulated signal transmission lines in the optical transmitter 4, the optical fiber transmission line 5 and the batched FM-modulated signal transmission line in the optical receiver 8.

As described above, the delay equalizer 2 can equalize the delay deviation of the whole system, that is, on the batched FM-modulated signal transmission lines of the optical transmitter 4, the optical fiber transmission line 5 and the optical receiver 8, thus reducing the delay distortion stemming from the delay deviation to realize a high-quality transmission of the frequency-multiplexed multi-channel signals.

(Fifth Optical Transmitter According to the Invention)

A fifth optical transmitter according to the present invention is constructed with the delay equalizer 2 in the optical transmitter shown in Fig. 16 being replaced with the delay equalizer according to the fifth embodiment (see Fig. 7).

With this arrangement, in the optical transmitter 4, frequency-multiplexed multi-channel signals inputted are FM-modulated in batches in the FM modulator 1. Subsequently, the delay equalizer 2 adds, to the obtained batched FM-modulated signals, a delay equalization quantity needed for equalizing a delay deviation in the batched FM-modulated signal transmission line in the optical transmitter 4. Following this, the batched FM-modulated signals are

inputted to the optical modulator 3 where signal light is intensity-modulated and optically transmitted through the optical fiber transmission line 5. In this case, since the delay equalizer 2 is constructed according to the fifth embodiment, although a simple circuit arrangement is put to use, the center frequency causing a variation of the delay characteristic is controllable through the voltage control from the external to vary and the delay equalization quantity is controllable from the external, which provides the optimal delay equalization characteristic with respect to the delay deviation on the batched FM-modulated signal transmission line in the optical transmitter 4.

As described above, the delay equalizer 2 can equalize the delay deviation of the batched FM-modulated signal transmission line in the optical transmitter 4, thus reducing the delay distortion stemming from the delay deviation so that high-quality transmission of frequency-multiplexed multi-channel signals is realizable.

(Fifth Optical Transmission System Using Optical Transmitter According to the Invention)

In a fifth optical transmission system using an optical transmitter according to the present invention, the delay equalizer 2 according to the fifth embodiment (see Fig. 7) is used in place of the delay equalizer 2 in the above-described first optical transmission system (see Fig. 17).

With this configuration, frequency-multiplexed multi-channel signals inputted to the optical transmitter 4 are FM-modulated in batches in the FM modulator 1. The batched FM-modulated signals obtained in this way are inputted to the delay equalizer 2 which

introduces a delay equalization quantity needed for equalizing the entire delay deviation on the batched FM-modulated signal transmission line in the optical transmitter 4, the optical fiber transmission line 5 and the batched FM-modulated signal transmission line in the optical receiver 8, and then outputted to the optical modulator 3 where signal light is intensity-modulated and optically transmitted through the optical fiber transmission line 5. In the optical receiver 8, the transmitted batched FM-modulated signals are optical/electrical-converted in the optical receive unit 6 and FM-demodulated in the FM demodulator 7, thereby regenerating the frequency-multiplexed multi-channel signals. In this case, since the delay equalizer 2 according to the fifth embodiment is put to use, the center frequency causing variation of the delay characteristic is controllable through the voltage control from the external to vary and the delay equalization quantity is variable, which provides the optimal delay equalization characteristic with respect to the delay deviation on the batched FM-modulated signal transmission lines in the optical transmitter 4, the optical fiber transmission line 5 and the batched FM-modulated signal transmission line in the optical receiver 8.

As described above, the delay equalizer 2 can equalize the delay deviation of the whole system, that is, on the batched FM-modulated signal transmission lines of the optical transmitter 4, the optical fiber transmission line 5 and the optical receiver 8, thus reducing the delay distortion stemming from the delay deviation to realize a high-quality transmission of the frequency-multiplexed multi-channel signals.

(Sixth Optical Transmitter According to the Invention)

A sixth optical transmitter according to the present invention is constructed with the delay equalizer 2 in the optical transmitter shown in Fig. 16 being replaced with the delay equalizer according to the sixth embodiment (see Fig. 8).

With this arrangement, in the optical transmitter 4, frequency-multiplexed multi-channel signals inputted are FM-modulated in batches in the FM modulator 1. Subsequently, the delay equalizer 2 introduces, into the obtained batched FM-modulated signals, a delay equalization quantity needed for equalizing a delay deviation in the batched FM-modulated signal transmission line in the optical transmitter 4. Following this, the batched FM-modulated signals are inputted to the optical modulator 3 where signal light is intensity-modulated and optically transmitted through the optical fiber transmission line 5. In this case, since the delay equalizer 2 is constructed with a delay equalizer, in which a plurality of delay equalizing sections #1, #2, ..., #N cascade-connected, according to the sixth embodiment, each of the center frequencies f_1 , f_2 , f_3 (f_N) for delay-equalizing the delay equalizing sections #1, #2, ..., #N is determined according to resonance frequency of each of the resonance circuits comprising an inductor and a capacitor, and the delay equalizing sections #1, #2, ..., #N have different delay equalization center frequencies, respectively, and further the resistance value of the variable resistor of each of the delay equalizing sections #1, #2, ..., #N is independently controlled to vary the delay equalization quantity,

which permits free variation of the delay equalization characteristic over a wide band of frequencies so that it is possible to provide an optimal delay equalization characteristic with respect to the delay deviation on the batched FM-modulated signal transmission line in the optical transmitter 4 over a wide band of frequencies.

As described above, the delay equalizer 2 can equalize the delay deviation on the batched FM-modulated signal transmission line in the optical transmitter 4, thus reducing the delay distortion stemming from the delay deviation so that high-quality transmission of frequency-multiplexed multi-channel signals is realizable.

(Sixth Optical Transmission System Using Optical Transmitter According to the Invention)

In a sixth optical transmission system using an optical transmitter according to the present invention, the delay equalizer 2 according to the sixth embodiment (see Fig. 8) is used in place of the delay equalizer 2 in the above-described first optical transmission system (see Fig. 17).

With this configuration, frequency-multiplexed multi-channel signals inputted to the optical transmitter 4 are FM-modulated in batches in the FM modulator 1. The batched FM-modulated signals obtained in this way are inputted to the delay equalizer 2 which introduces a delay equalization quantity needed for equalizing the entire delay deviation on the batched FM-modulated signal transmission line in the optical transmitter 4, the optical fiber transmission line 5 and the batched FM-modulated signal transmission

line in the optical receiver 8, and then outputted to the optical modulator 3 where signal light is intensity-modulated and optically transmitted through the optical fiber transmission line 5. In the optical receiver 8, the transmitted batched FM-modulated signals are

5 optical/electrical-converted in the optical receive unit 6 and FM-demodulated in the FM demodulator 7, thereby regenerating the frequency-multiplexed multi-channel signals.

In this case, since the delay equalizer 2 is constructed with a delay equalizer, in which a plurality of delay equalizing sections #1, #2, ..., #N cascade-connected, according to the sixth embodiment, each of the
 10 center frequencies f_1 , f_2 , f_3 (f_N) for delay equalization in the delay equalizing sections #1, #2, ..., #N is determined by the resonance frequency of each of the resonance circuits comprising an inductor and a capacitor, and the delay equalizing sections #1, #2, ..., #N have
 15 different delay equalization center frequencies, respectively, and further the resistance value of the variable resistor of each of the delay equalizing sections #1, #2, ..., #N is independently controlled to vary the delay equalization quantity, which permits arbitrary variation of the delay equalization characteristic over a wide band of frequencies so
 20 that it is possible to provide an optimal delay equalization characteristic with respect to the delay deviation on the batched FM-modulated signal transmission lines of the optical transmitter 4, the optical fiber transmission line 5 and the optical receiver 8 over a wide band of frequencies.

As described above, the delay equalizer 2 can equalize the delay deviation of the whole system, that is, on the batched FM-modulated signal transmission lines of the optical transmitter 4, the optical fiber transmission line 5 and the optical receiver 8, thus reducing the delay distortion stemming from the delay deviation to realize a high-quality transmission of the frequency-multiplexed multi-channel signals.

(Seventh Optical Transmitter According to the Invention)

A seventh optical transmitter according to the present invention is constructed with the delay equalizer 2 in the optical transmitter shown in Fig. 16 being replaced with the delay equalizer according to the seventh embodiment (see Fig. 12).

With this arrangement, in the optical transmitter 4, frequency-multiplexed multi-channel signals inputted are FM-modulated in batches in the FM modulator 1. Subsequently, the delay equalizer 2 introduces, into the obtained batched FM-modulated signals, a delay equalization quantity needed for equalizing a delay deviation in the batched FM-modulated signal transmission line in the optical transmitter 4. Following this, the batched FM-modulated signals are inputted to the optical modulator 3 where signal light is intensity-modulated and optically transmitted through the optical fiber transmission line 5. In this case, since the delay equalizer 2 is constructed with a delay equalizer according to the seventh embodiment, the capacitance of the variable capacitor is controlled to vary the resonance frequency of the resonance circuit comprising an inductor and a capacitor, thus varying each of the center frequencies f_1 ,

f2, f3 (fN) for determining the delay characteristic, and the resistance of the variable resistor of each of the delay equalizing sections #1, #2, ..., #N is controlled to vary the delay equalization quantity, thus permitting arbitrary variation of the delay equalization characteristic over a wide band of frequencies so that it is possible to provide an optimal delay equalization characteristic with respect to the delay deviation on the batched FM-modulated signal transmission line in the optical transmitter 4 over a wide band of frequencies.

As described above, the delay equalizer 2 can equalize the delay deviation on the batched FM-modulated signal transmission line in the optical transmitter 4, thus reducing the delay distortion stemming from the delay deviation so that high-quality transmission of frequency-multiplexed multi-channel signals is realizable.

(Seventh Optical Transmission System Using Optical Transmitter

According to the Invention)

In a seventh optical transmission system using an optical transmitter according to the present invention, the delay equalizer 2 according to the seventh embodiment (see Fig. 12) is used in place of the delay equalizer 2 in the above-described first optical transmission system (see Fig. 17).

With this configuration, frequency-multiplexed multi-channel signals inputted to the optical transmitter 4 are FM-modulated in batches in the FM modulator 1. The batched FM-modulated signals obtained in this way are inputted to the delay equalizer 2 which introduces a delay equalization quantity needed for equalizing the

entire delay deviation on the batched FM-modulated signal transmission line in the optical transmitter 4, the optical fiber transmission line 5 and the batched FM-modulated signal transmission line in the optical receiver 8, and then outputted to the optical modulator 3 where signal light is intensity-modulated and optically transmitted through the optical fiber transmission line 5. In the optical receiver 8, the transmitted batched FM-modulated signals are optical/electrical-converted in the optical receive unit 6 and FM-demodulated in the FM demodulator 7, thereby regenerating the frequency-multiplexed multi-channel signals.

In this case, since the delay equalizer 2 is constructed with a delay equalizer according to the seventh embodiment, the capacitance of the variable capacitor is controlled to vary the resonance frequency of the resonance circuit comprising an inductor and a capacitor, thus varying each of the center frequencies f_1 , f_2 , f_3 (f_N) for determining the delay characteristic, and the resistance of the variable resistor of each of the delay equalizing sections #1, #2, ..., #N is controlled to vary the delay equalization quantity, thus permitting arbitrary variation of the delay equalization characteristic over a wide band of frequencies so that it is possible to provide an optimal delay equalization characteristic with respect to the delay deviation on the batched FM-modulated signal transmission lines of the optical transmitter 4, the optical fiber transmission line 5 and the optical receiver 8 over a wide band of frequencies.

As described above, the delay equalizer 2 can equalize the delay deviation of the whole system, that is, on the batched FM-modulated signal transmission lines of the optical transmitter 4, the optical fiber transmission line 5 and the optical receiver 8, thus reducing the delay distortion stemming from the delay deviation to realize a high-quality transmission of the frequency-multiplexed multi-channel signals.

(Eighth Optical Transmitter according to the Invention)

An eighth optical transmitter according to the present invention is constructed with the delay equalizer 2 in the optical transmitter shown in Fig. 16 being replaced with the delay equalizer according to the eighth embodiment (see Fig. 13).

With this arrangement, in the optical transmitter 4, frequency-multiplexed multi-channel signals inputted are FM-modulated in batches in the FM modulator 1. Subsequently, the delay equalizer 2 introduces, into the obtained batched FM-modulated signals, a delay equalization quantity needed for equalizing a delay deviation in the batched FM-modulated signal transmission line in the optical transmitter 4. Following this, the batched FM-modulated signals are inputted to the optical modulator 3 where signal light is intensity-modulated and optically transmitted through the optical fiber transmission line 5. In this case, since the delay equalizer 2 is constructed with a delay equalizer according to the eighth embodiment, a circuit for controlling the current flowing through a PIN diode is placed in each of the delay equalizing sections #1, #2, ..., #N, and the voltage is controlled from the external to independently control the

current flowing through the PIN diode in each of the delay equalizing sections #1, #2, ..., #N for varying the internal resistance value, thus permitting arbitrary variation of the delay equalization characteristic over a wide band of frequencies so that it is possible to provide an
5 optimal delay equalization characteristic with respect to the delay deviation on the batched FM-modulated signal transmission line in the optical transmitter 4 over a wide band of frequencies.

As described above, the delay equalizer 2 can equalize the delay deviation on the batched FM-modulated signal transmission line in the
10 optical transmitter 4, thus reducing the delay distortion stemming from the delay deviation so that high-quality transmission of frequency-multiplexed multi-channel signals is realizable.
(Eighth Optical Transmission System Using Optical Transmitter According to the Invention)

15 In an eighth optical transmission system using an optical transmitter according to the present invention, the delay equalizer 2 according to the eighth embodiment (see Fig. 13) is used in place of the delay equalizer 2 in the above-described first optical transmission system (see Fig. 17).

20 With this configuration, frequency-multiplexed multi-channel signals inputted to the optical transmitter 4 are FM-modulated in batches in the FM modulator 1. The batched FM-modulated signals obtained in this way are inputted to the delay equalizer 2 which introduces a delay equalization quantity needed for equalizing the
25 entire delay deviation on the batched FM-modulated signal

transmission line in the optical transmitter 4, the optical fiber transmission line 5 and the batched FM-modulated signal transmission line in the optical receiver 8, and then outputted to the optical modulator 3 where signal light is intensity-modulated and optically transmitted through the optical fiber transmission line 5. In the optical receiver 8, the transmitted batched FM-modulated signals are optical/electrical-converted in the optical receive unit 6 and FM-demodulated in the FM demodulator 7, thereby regenerating the frequency-multiplexed multi-channel signals.

10 In this case, since the delay equalizer 2 is constructed with a delay equalizer according to the eighth embodiment, a circuit for controlling the current flowing through a PIN diode is placed in each of the delay equalizing sections #1, #2, ..., #N, and the voltage is controlled from the external to independently control the current flowing through the PIN diode in each of the delay equalizing sections #1, #2, ..., #N for varying the internal resistance value, thus permitting arbitrary variation of the delay equalization characteristic over a wide band of frequencies so that it is possible to provide an optimal delay equalization characteristic with respect to the delay deviation on the batched FM-modulated signal transmission lines of the optical transmitter 4, the optical fiber transmission line 5 and the optical receiver 8 over a wide band of frequencies.

As described above, the delay equalizer 2 can equalize the delay deviation of the whole system, that is, on the batched FM-modulated signal transmission lines of the optical transmitter 4, the optical fiber

transmission line 5 and the optical receiver 8, thus reducing the delay distortion stemming from the delay deviation to realize a high-quality transmission of the frequency-multiplexed multi-channel signals.

(Ninth Optical Transmitter According to the Invention)

5 A ninth optical transmitter according to the present invention is constructed with the delay equalizer 2 in the optical transmitter shown in Fig. 16 being replaced with the delay equalizer according to the ninth embodiment (see Fig. 14).

10 With this arrangement, in the optical transmitter 4, frequency-multiplexed multi-channel signals inputted are FM-modulated in batches in the FM modulator 1. Subsequently, the delay equalizer 2 introduces, into the obtained batched FM-modulated signals, a delay equalization quantity needed for equalizing a delay deviation in the batched FM-modulated signal transmission line in the optical
15 transmitter 4. Following this, the batched FM-modulated signals are inputted to the optical modulator 3 where signal light is intensity-modulated and optically transmitted through the optical fiber transmission line 5. In this case, since the delay equalizer 2 is constructed with a delay equalizer according to the ninth embodiment,
20 a circuit for controlling the voltage value across a voltage variable capacitor is placed in each of the delay equalizing sections #1, #2, ..., #N, and the voltage value across a voltage variable capacitor in each of the delay equalizing sections #1, #2, ..., #N is controlled independently from the external to vary the resonance frequency of the
25 resonance circuit comprising an inductor and a capacitor, thus freely

varying each of the center frequencies f_1 , f_2 , f_3 (f_N) for determining the delay characteristic of each of the delay equalizing sections #1, #2, ..., #N. In addition, the resistance of the variable resistor of each of the delay equalizing sections #1, #2, ..., #N is controlled independently
5 from the external to vary the delay equalization quantity, thus permitting arbitrary variation of the delay equalization quantity over a wide band of frequencies so that it is possible to provide an optimal delay equalization characteristic with respect to the delay deviation on the batched FM-modulated signal transmission line in the optical
10 transmitter 4 over a wide band of frequencies.

As described above, the delay equalizer 2 can equalize the delay deviation on the batched FM-modulated signal transmission line in the optical transmitter 4, thus reducing the delay distortion stemming from the delay deviation so that high-quality transmission of
15 frequency-multiplexed multi-channel signals is realizable.

(Ninth Optical Transmission System Using Optical Transmitter According to the Invention)

In a ninth optical transmission system using an optical transmitter according to the present invention, the delay equalizer 2
20 according to the ninth embodiment (see Fig. 14) is used in place of the delay equalizer 2 in the above-described first optical transmission system (see Fig. 17).

With this configuration, frequency-multiplexed multi-channel signals inputted to the optical transmitter 4 are FM-modulated in
25 batches in the FM modulator 1. The batched FM-modulated signals

obtained in this way are inputted to the delay equalizer 2 which introduces a delay equalization quantity needed for equalizing the entire delay deviation on the batched FM-modulated signal transmission line in the optical transmitter 4, the optical fiber transmission line 5 and the batched FM-modulated signal transmission line in the optical receiver 8, and then outputted to the optical modulator 3 where signal light is intensity-modulated and optically transmitted through the optical fiber transmission line 5. In the optical receiver 8, the transmitted batched FM-modulated signals are optical/electrical-converted in the optical receive unit 6 and FM-demodulated in the FM demodulator 7, thereby regenerating the frequency-multiplexed multi-channel signals.

In this case, since the delay equalizer 2 is constructed with a delay equalizer according to the ninth embodiment, a circuit for controlling the voltage value across a voltage variable capacitor is placed in each of the delay equalizing sections #1, #2, ..., #N, and the voltage value across a voltage variable capacitor in each of the delay equalizing sections #1, #2, ..., #N is controlled independently from the external to vary the resonance frequency of the resonance circuit comprising an inductor and a capacitor, thus freely varying each of the center frequencies f_1 , f_2 , f_3 (f_N) for determining the delay characteristic of each of the delay equalizing sections #1, #2, ..., #N. In addition, the resistance of the variable resistor of each of the delay equalizing sections #1, #2, ..., #N is controlled independently from the external to vary the delay equalization quantity, thus permitting arbitrary variation

of the delay equalization characteristic over a wide band of frequencies so that it is possible to provide an optimal delay equalization characteristic with respect to the delay deviation on the batched FM-modulated signal transmission lines of the optical transmitter 4, the optical fiber transmission line 5 and the optical receiver 8 over a wide band of frequencies.

As described above, the delay equalizer 2 can equalize the delay deviation of the whole system, that is, on the batched FM-modulated signal transmission lines of the optical transmitter 4, the optical fiber transmission line 5 and the optical receiver 8, thus reducing the delay distortion stemming from the delay deviation to realize a high-quality transmission of the frequency-multiplexed multi-channel signals.

(Tenth Optical Transmitter According to the Invention)

A tenth optical transmitter according to the present invention is constructed with the delay equalizer 2 in the optical transmitter shown in Fig. 16 being replaced with the delay equalizer according to the tenth embodiment (see Fig. 15).

With this arrangement, in the optical transmitter 4, frequency-multiplexed multi-channel signals inputted are FM-modulated in batches in the FM modulator 1. Subsequently, the delay equalizer 2 introduces, into the obtained batched FM-modulated signals, a delay equalization quantity needed for equalizing a delay deviation in the batched FM-modulated signal transmission line in the optical transmitter 4. Following this, the batched FM-modulated signals are inputted to the optical modulator 3 where signal light is

intensity-modulated and optically transmitted through the optical fiber transmission line 5. In this case, since the delay equalizer 2 is constructed with a delay equalizer according to the tenth embodiment, a circuit for controlling the voltage value across a voltage variable capacitor is placed in each of the delay equalizing sections #1, #2, ..., #N, and the voltage value across a voltage variable capacitor in each of the delay equalizing sections #1, #2, ..., #N is controlled independently from the external to vary the resonance frequency of the resonance circuit comprising an inductor and a capacitor, thus freely varying each of the center frequencies f_1 , f_2 , f_3 (f_N) for determining the delay characteristic of each of the delay equalizing sections #1, #2, ..., #N. In addition, a current flowing through a PIN diode in each of the delay equalizing sections #1, #2, ..., #N is controlled independently through a voltage variation from the external to vary its internal resistance, thus permitting arbitrary variation of the delay equalization quantity over a wide band so that it is possible to provide an optimal delay equalization characteristic with respect to the delay deviation on the batched FM-modulated signal transmission line in the optical transmitter 4 over a wide band of frequencies.

As described above, the delay equalizer 2 can equalize the delay deviation on the batched FM-modulated signal transmission line in the optical transmitter 4, thus reducing the delay distortion stemming from the delay deviation so that high-quality transmission of frequency-multiplexed multi-channel signals is realizable.

(Tenth Optical Transmission System Using Optical Transmitter
According to the Invention)

In a tenth optical transmission system using an optical transmitter according to the present invention, the delay equalizer 2 according to the tenth embodiment (see Fig. 15) is used in place of the delay equalizer 2 in the above-described first optical transmission system (see Fig. 17).

With this configuration, frequency-multiplexed multi-channel signals inputted to the optical transmitter 4 are FM-modulated in batches in the FM modulator 1. The batched FM-modulated signals obtained in this way are inputted to the delay equalizer 2 which introduces a delay equalization quantity needed for equalizing the entire delay deviation on the batched FM-modulated signal transmission line in the optical transmitter 4, the optical fiber transmission line 5 and the batched FM-modulated signal transmission line in the optical receiver 8, and then outputted to the optical modulator 3 where signal light is intensity-modulated and optically transmitted through the optical fiber transmission line 5. In the optical receiver 8, the transmitted batched FM-modulated signals are optical/electrical-converted in the optical receive unit 6 and FM-demodulated in the FM demodulator 7, thereby regenerating the frequency-multiplexed multi-channel signals.

In this case, since the delay equalizer 2 is constructed with a delay equalizer according to the tenth embodiment, a circuit for controlling the voltage value across a voltage variable capacitor is placed in each

of the delay equalizing sections #1, #2, ..., #N, and the voltage value across a voltage variable capacitor in each of the delay equalizing sections #1, #2, ..., #N is controlled independently from the external to vary the resonance frequency of the resonance circuit comprising an inductor and a capacitor, thus freely varying each of the center frequencies f_1 , f_2 , f_3 (f_N) for determining the delay characteristic of each of the delay equalizing sections #1, #2, ..., #N. In addition, a current flowing through a PIN diode in each of the delay equalizing sections #1, #2, ..., #N is controlled independently through voltage control from the external to vary its internal resistance, thus permitting arbitrary variation of the delay equalization characteristic over a wide band so that it is possible to provide an optimal delay equalization characteristic with respect to the delay deviation on the batched FM-modulated signal transmission lines of the optical transmitter 4, the optical fiber transmission line 5 and the optical receiver 8 over a wide band of frequencies.

As described above, the delay equalizer 2 can equalize the delay deviation of the whole system, that is, on the batched FM-modulated signal transmission lines of the optical transmitter 4, the optical fiber transmission line 5 and the optical receiver 8, thus reducing the delay distortion stemming from the delay deviation to realize a high-quality transmission of the frequency-multiplexed multi-channel signals.

It should be understood that the present invention is not limited to the above-described embodiment, and that it is intended to cover all changes and modifications of the embodiments of the invention herein

1911 1912 1913 1914 1915 1916 1917 1918 1919 1920 1921 1922 1923 1924 1925 1926 1927 1928 1929 1930 1931 1932 1933 1934 1935 1936 1937 1938 1939 1940 1941 1942 1943 1944 1945 1946 1947 1948 1949 1950 1951 1952 1953 1954 1955 1956 1957 1958 1959 1960 1961 1962 1963 1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050 2051 2052 2053 2054 2055 2056 2057 2058 2059 2060 2061 2062 2063 2064 2065 2066 2067 2068 2069 2070 2071 2072 2073 2074 2075 2076 2077 2078 2079 2080 2081 2082 2083 2084 2085 2086 2087 2088 2089 2090 2091 2092 2093 2094 2095 2096 2097 2098 2099 2100 2101 2102 2103 2104 2105 2106 2107 2108 2109 2110 2111 2112 2113 2114 2115 2116 2117 2118 2119 2120 2121 2122 2123 2124 2125 2126 2127 2128 2129 2130 2131 2132 2133 2134 2135 2136 2137 2138 2139 2140 2141 2142 2143 2144 2145 2146 2147 2148 2149 2150 2151 2152 2153 2154 2155 2156 2157 2158 2159 2160 2161 2162 2163 2164 2165 2166 2167 2168 2169 2170 2171 2172 2173 2174 2175 2176 2177 2178 2179 2180 2181 2182 2183 2184 2185 2186 2187 2188 2189 2190 2191 2192 2193 2194 2195 2196 2197 2198 2199 2200 2201 2202 2203 2204 2205 2206 2207 2208 2209 2210 2211 2212 2213 2214 2215 2216 2217 2218 2219 2220 2221 2222 2223 2224 2225 2226 2227 2228 2229 2230 2231 2232 2233 2234 2235 2236 2237 2238 2239 2240 2241 2242 2243 2244 2245 2246 2247 2248 2249 2250 2251 2252 2253 2254 2255 2256 2257 2258 2259 2260 2261 2262 2263 2264 2265 2266 2267 2268 2269 2270 2271 2272 2273 2274 2275 2276 2277 2278 2279 2280 2281 2282 2283 2284 2285 2286 2287 2288 2289 2290 2291 2292 2293 2294 2295 2296 2297 2298 2299 2300 2301 2302 2303 2304 2305 2306 2307 2308 2309 2310 2311 2312 2313 2314 2315 2316 2317 2318 2319 2320 2321 2322 2323 2324 2325 2326 2327 2328 2329 2330 2331 2332 2333 2334 2335 2336 2337 2338 2339 2340 2341 2342 2343 2344 2345 2346 2347 2348 2349 2350 2351 2352 2353 2354 2355 2356 2357 2358 2359 2360 2361 2362 2363 2364 2365 2366 2367 2368 2369 2370 2371 2372 2373 2374 2375 2376 2377 2378 2379 2380 2381 2382 2383 2384 2385 2386 2387 2388 2389 2390 2391 2392 2393 2394 2395 2396 2397 2398 2399 2400 2401 2402 2403 2404 2405 2406 2407 2408 2409 2410 2411 2412 2413 2414 2415 2416 2417 2418 2419 2420 2421 2422 2423 2424 2425 2426 2427 2428 2429 2430 2431 2432 2433 2434 2435 2436 2437 2438 2439 2440 2441 2442 2443 2444 2445 2446 2447 2448 2449 2450 2451 2452 2453 2454 2455 2456 2457 2458 2459 2460 2461 2462 2463 2464 2465 2466 2467 2468 2469 2470 2471 2472 2473 2474 2475 2476 2477 2478 2479 2480 2481 2482 2483 2484 2485 2486 2487 2488 2489 2490 2491 2492 2493 2494 2495 2496 2497 2498 2499 2500 2501 2502 2503 2504 2505 2506 2507 2508 2509 2510 2511 2512 2513 2514 2515 2516 2517 2518 2519 2520 2521 2522 2523 2524 2525 2526 2527 2528 2529 2530 2531 2532 2533 2534 2535 2536 2537 2538 2539 2540 2541 2542 2543 2544 2545 2546 2547 2548 2549 2550 2551 2552 2553 2554 2555 2556 2557 2558 2559 2560 2561 2562 2563 2564 2565 2566 2567 2568 2569 2570 2571 2572 2573 2574 2575 2576 2577 2578 2579 2580 2581 2582 2583 2584 2585 2586 2587 2588 2589 2590 2591 2592 2593 2594 2595 2596 2597 2598 2599 2600 2601 2602 2603 2604 2605 2606 2607 2608 2609 2610 2611 2612 2613 2614 2615 2616 2617 2618 2619 2620 2621 2622 2623 2624 2625 2626 2627 2628 2629 2630 2631 2632 2633 2634 2635 2636 2637 2638 2639 2640 2641 2642 2643 2644 2645 2646 2647 2648 2649 2650 2651 2652 2653 2654 2655 2656 2657 2658 2659 2660 2661 2662 2663 2664 2665 2666 2667 2668 2669 2670 2671 2672 2673 2674 2675 2676 2677 2678 2679 2680 2681 2682 2683 2684 2685 2686 2687 2688 2689 2690 2691 2692 2693 2694 2695 2696 2697 2698 2699 2700 2701 2702 2703 2704 2705 2706 2707 2708 2709 2710 2711 2712 2713 2714 2715 2716 2717 2718 2719 2720 2721 2722 2723 2724 2725 2726 2727 2728 2